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Information Technology Laboratory

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Building Information Modeling (BIM) Primer

Report 1: Facility Life-cycle Process and Technology Innovation

Sirobe D. Carstafhnur and DeAnna L. Dixon

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Report 1 of a series

Abstract

The architecture, engineering, and construction industries are pursuing process and technological innovations to save time and money and to enhance the quality of projects through the design, construction, and handover phases. Building Information Modeling (BIM) is a new technology designed to improve this process.

The U.S. Army Engineer Research and Development Center (ERDC) is making an effort to implement BIM. The U.S. Army Corps of Engineers (USACE), New York District (CENAN), requested assistance from the CAD/BIM Technology Center at ERDC's Information Technology Laboratory, Vicksburg, Mississippi, to research the benefits of BIM throughout the life-cycle process with the aim of improving the quality of its services and provide a competitive advantage. The Asymmetric Warfare Group Complex (AWG) at Fort Meade, Maryland, served as the pilot project, depicting the BIM process during the design, construction, and handover phases. ERDC, CENAN designers, Bentley Systems, and the Fort Meade Department of Public Works (DPW) joined together to capture and deliver real-time building information.

This BIM Primer report documents changes in the building process and the supplemental software required to deliver accurate record drawings and data documentation. This report covers the initial parts of the project, including research of BIM products and the design phase of the AWG endeavor. During the early stages, Fort Meade DPW personnel outlined the data required for operations and maintenance, as well as facility management software they are using and would like to use. ERDC believes that including the end user in the design phase will result in the extension of BIM benefits in the latter phases of a building's life cycle.

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Preface

This study was conducted for the U.S. Army Corps of Engineers (USACE), New York District (CENAN).

The work was performed by the CAD/BIM Center of the Software, Engineering, and Informatics Division (SEID), U.S. Army Engineer Research and Development Center (ERDC), Information Technology Laboratory (ITL), Vicksburg, Mississippi.

At the time the research was conducted, Edward Huell was Acting Chief, SEID. The Deputy Director of ITL was Dr. Deborah Dent, and the Director was Dr. Reed Mosher.

At the time of publication, COL Kevin J. Wilson was Commander and Executive Director of ERDC, and Dr. Jeffery P. Holland was Director.

1 Introduction

1.1 BIM background and industry overview

Building Information Modeling (BIM) first emerged in the architecture, engineering, and construction industries during the early 1990s. The process consists of demonstrating graphical and non-graphical aspects of the full building life cycle and creating a single storage space of design, construction documents, specifications, and schedules. The goal is to capture facility data from its authoritative sources and exchange this data in a format all building owners can access. BIM generates real-time, 3-D models to increase productivity in building design and construction.

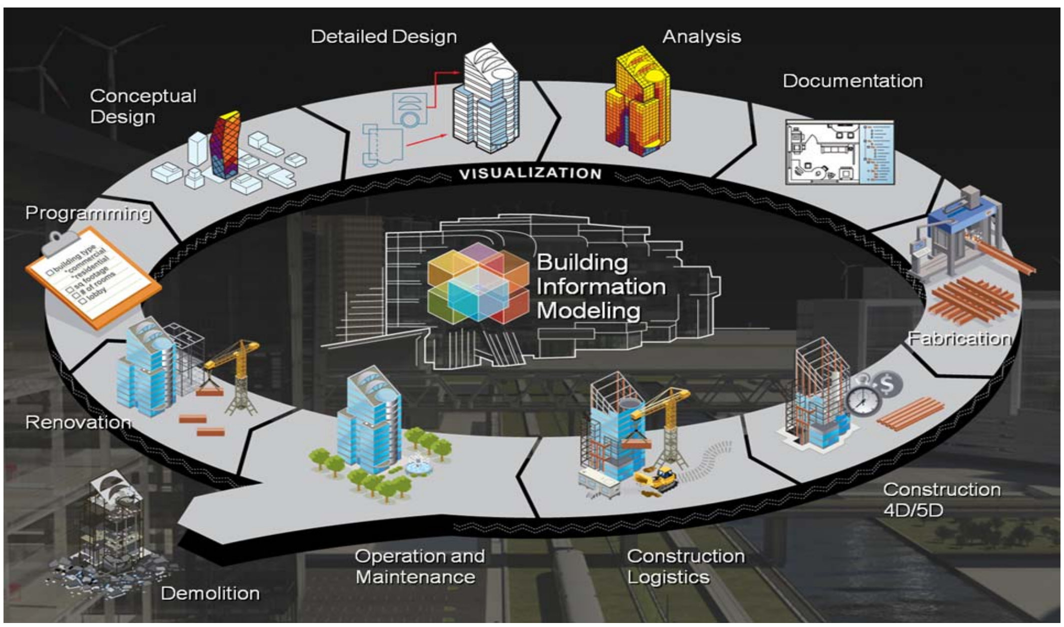

Figure 1. The Building Information Modeling (BIM) process (Dispenza 2011).

It was believed that BIM would deliver substantial cuts in cost and time. Approximately 20 years after its initial appearance, BIM made good on its promise. In McGraw Hill Construction's SmartMarket Report (2009), it was said that BIM provides a competitive advantage, improves productivity, and decreases the chance of litigation. The most significant impact has been the return of investment (ROI) on projects. In the overall market, seven in 10 BIM users reported positive returns. More specifically, one in five BIM users has a ROI greater than 50% (McGraw Hill 2009). Also, studies have found that ROI increases with accrued experience in the BIM process and technology.

Table 1. Savings of BIM utilization: preliminary, concept, and detail design (King 2008).

Benefit Area	Description	Benefits	Cost Benefit
Coordination and clashing	The virtual model provides an effective and efficient means of coordinating the design elements on a scheme.	- Clash-free, coordinated model - Lower design cost - Less burden on design team	5% saved in design cost
Material schedules	Component and material schedules are generated automatically and accurately from the 3-D model, and can be transferred easily to and from proprietary databases or spreadsheets to help estimators, purchasers, and designers.	- Quick production of error-free schedules - Smaller estimating teams - Better awareness of costs as the design develops	1% saved in design cost
Stakeholder awareness	The virtual model is a powerful tool that helps to convey complicated design aspects to stakeholders, and information can be tailored easily to suit the audience.	- Improved stakeholder awareness - Easier to secure buy-in earlier in a project - More likely to encourage a good response from potential tenderers	1% saved in design cost
Design efficiency	A model centric approach makes it more realistic for designers make fewer mistakes the first time and to consider more design options.	- Greater design efficiency - Better value for the client - More profit for the designers and no erosion of margin in construction	3% saved in design cost

Table 2. Savings of BIM utilization: construction and commissioning (King 2008).

Benefit Area	Description	Benefits	Cost Benefit
Trade packages	Using virtual model, site teams can produce trade package information easily and accurately for tendering and managing subcontractors.	- Easier compilation of tender information - Information for tenderers that is correct, complete, and consistent - Lower tender risk contingencies	1% saved in design cost
Construction planning	Virtual models can be linked to master and sub-project programs using proprietary software tools, enabling the work and revisions to be conveyed graphically.	- Improved project programming and better understanding of activities - Better informed stakeholders - Improved health and safety training of site terms	0.25% saved in design cost
Clash management	Design coordination helps to prevent clashes from reaching the site, thereby eliminating both construction waste and disruption.	- Clash-free, coordinated construction - Lower cost due to less waste and fewer disruptions - Less burden on construction team	5% saved in design cost
As-built information	As-built information can be produced easily and more accurately because the model is kept current through the construction period, ensuring that the facilities manager will receive high-quality data.	- Easier to produce high-quality as-built data for handover - Lower cost of producing as-built information	5% saved in design cost

1.2 Interoperability

BIM not only offers improvements in speed, cost, and quality, but also provides interoperability, the use of multiple BIM software to exchange data effectively (Burt 2009). This allows BIM to be read by multiple software programs. One way of achieving interoperability is using the Industry Foundation Class (IFC) file format. IFC is an open-standard format that describes and shares information used within the building and facility management industry (Burt 2009).

BIM interoperability is a great technology; however, there are some complications with using this process. Software vendors have their own versions of BIM that might cause technical issues when exchanging BIM models. To solve this problem, BIM standards based on open architecture and data exchange will need to be adopted. One major concern for software designers is the depth at which interoperability should be accessible. Should the models only be able to be read in various platforms, or should they be accessible for editing as well (McNamara 2011)? An open exchange in models and data is beneficial as far as design, but raises legal concerns with ownership of the model (Hofbauer 2011).

1.3 The effort to extend BIM to facility management

Previously, the advantages of BIM have ended at the construction phase. According to the National Institute of Standards and Technology (NIST) Interoperability Study of 2004, two-thirds of the 85% of life-cycle cost is lost to operations and maintenance (O&M) during building turnover. Due to the significant savings seen over the years in the design and construction phases, owners and facility managers have been focused on extending the benefits of BIM to the operations and maintenance phases of a facility's life cycle (Jordani 2010). Owners are taking the full responsibility of ensuring that the project team is on board with the objective to reap the full advantages of BIM by unveiling the needs of facility maintenance at the project kickoff meeting. Follow-through with the required technology and work flow increases the chances that FM data is collected and is accurate. Eli Lilly Company is living proof. In Engineering News-Record, the pharmaceutical firm revealed that quality assurance depends on continual data collection and verification throughout the project, not just at the end.

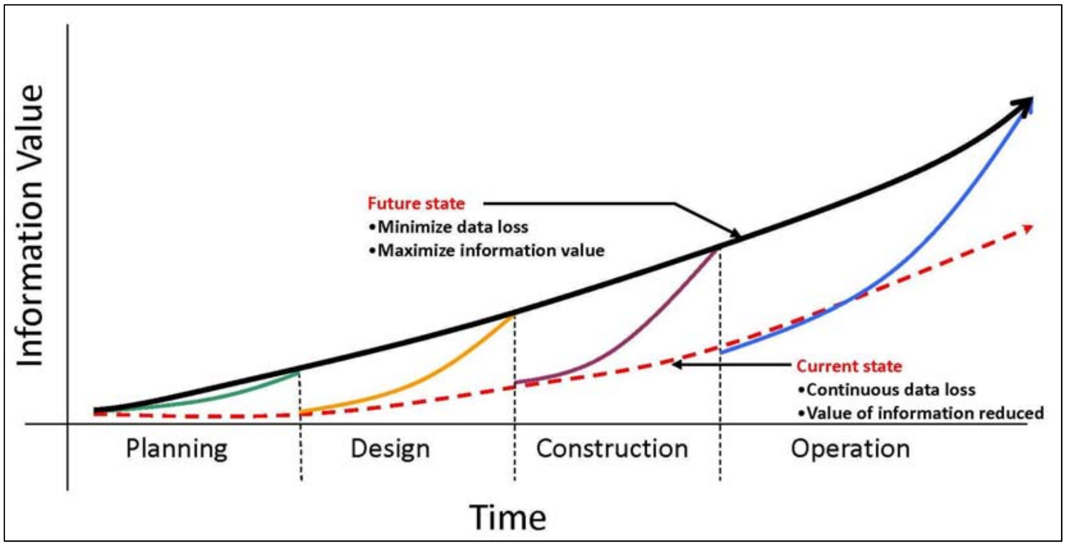

Figure 2. Information exchange losses throughout the life cycle (Singh and Dunn 2008).

Moreover, studies and field research have shown that the data needed for O&M includes information about equipment, such as model number, warranty date, serial numbers, installation date, and location. A small portion of this information is known during design, but most develops during construction. Traditionally, owners have not received this information until occupation of the facilities or as late as the reception of record drawings. Contractors and staff retrieve the information after equipment is installed, commissioned, and occupied. This prolongs hand-off and increases the chance of losing valuable data. Therefore, the user spends months and valuable dollars to recover the information needed to update warranties, repair and replace, and perform day-to-day operations. In regard to the equipment that is covered or placed within the walls, the information never is recovered. Facility managers must trust that what was installed matches the mandates in the specs and is documented accurately in the record drawings.

1.4 BIM and computerized maintenance management systems (CMMS)

Facility management encompasses multiple disciplines to ensure functionality of built environments by integrating people, place, process, and technology (IFMA 2011). With the introduction of a computerized maintenance management system (CMMS), information about the facility can be collected digitally and maintained on a single platform. CMMS, also known as computer-aided facility management (CAFM) or the latest term, facility management software (FM software), is defined as the software package that maintains a computer database intended to help maintenance workers and management make informed decisions about day-to-day operations and future needs. It has the ability to manage facility assets, as well as equipment conditions, histories, specifications, and costs. Using the software, managers can schedule preventive, reactive, and condition-based maintenance, and resource optimization. With software, BIM is now valuable beyond the construction phase.

2 Asymmetric Warfare Group (AWG) Complex

2.1 CENAN BIM manual and progressive efforts

The Asymmetric Warfare Group (AWG) Complex at Fort George G. Meade, Odenton, Maryland, served as the pilot project location to incorporate BIM throughout the design, construction, and handover phases. In this project, ERDC joined with CENAN designers, Bentley Systems, and Fort Meade Department of Public Works (DPW) to develop and implement the technology and business processes needed to quickly capture and deliver real-time building information. This report features research on BIM contractual language, directions for contractors to obtain items of interest, and the method to produce final deliverables. ERDC conducted research, project site visits, and numerous interviews to accomplish the vision of the BIM Primer.

CENAN was a likely candidate to shadow because it was an early adopter of BIM and published the *Office Manual for Building Information Modeling Projects*. The manual is a guide for CENAN BIM projects. The goal for CENAN BIM projects is to use technology to meet customer expectations and provide a BIM model for the future. The manual has three parts: BIM instructions, minimum submittal requirements, and the discipline-based BIM submittal requirements BIM + FM.

2.2 Context

The AWG Complex sits on the army installation of Fort George G. Meade. Fort Meade was established in 1917 with the construction of 1,460 buildings. Today, it is the fourth largest Army installation in the United States, and its 1,517 buildings sit on 5,067 acres. Its aim is to "enable critical national security missions by providing our customers and community the facilities and infrastructure they require, the quality of life they deserve and a safe, secure environment in which to work and live." The United States Cyber Command, along with the National Security Agency, U.S. Environmental Protection Agency, and the Defense Courier Service, are housed on the campus. Fort Meade's recent additions include the Defense Information Systems Agency (DISA) and the Department of Defense Media Activities.

Figure 3. Fort George G. Meade, Odenton, Maryland (GoogleEarth 2011).

CENAN has been asked by the Baltimore District to provide contract documents for the new Fort Meade DPW Contractor Building. The 14,000-square-ft, two-story building features offices, shops, storage, and work stations.

2.3 DPW assessment

2.3.1 Objective and execution

ERDC was assigned to investigate the required data of its clients in order to efficiently manage the building after turnover. CENAN asked ERDC to develop contractual language on what data should be delivered and the steps contractors should follow to ensure the deliverable.

ERDC, along with Bentley Systems, conducted a site assessment at Fort Meade. The aim was to identify specific requirements of the DPW to improve overall workflow and data tracking from building design through construction to operations and maintenance. Participants discussed data management and data integration requirements.

The topics of discussion were the:

1. Evaluation, review, and identification of the BIM content necessary for operations and maintenance;
2. Assessment of software and hardware capabilities and/or constraints; and
3. Identification of the stages of the BIM life cycle.

2.3.2 Key findings

ERDC uncovered issues DPW has with workflow and the record drawings beneficial to redeveloping the building life cycle. The issues that impact this project are (see appendix for full report):

1. Timing and quality of the data received:

   Record drawings and supplemental information often are delivered after the building has been commissioned and occupied by the tenant. Therefore, DPW doesn't have the sufficient information to properly service the building or effectively respond to repairs or emergencies. This results in a loss of man-hours and funds to duplicate information that should have been provided. Moreover, when the data is received, it contains many errors or is missing information due to poor quality assurance during construction. In the worst cases, documents are in digital formats that aren't compatible with DPW's software.

2. Commissioning:

   The new technological advancements in building systems have made equipment more complex than the skills of the DPW staff. If employees had been able to study the DPW's HVAC systems before equipment was specified, they would have been able to either make recommendations for equipment they could handle or request training while the installer was on site and under contract.

3. General Fund Enterprise Business System (GFEBS):

   DPW had used IBM Maximo and the maintenance management software IFS for logistics, operations, and maintenance. Now, GFEBS, the Army's new Web-enabled financial, asset and accounting management system, standardizes, streamlines, and shares critical data across the Army, Army National Guard, and Army Reserve.

The goal of GFEBS is to capture transactions and provide reliable data to better enable Army leadership to make decisions in support of warfighting capability. GFEBS will provide leaders with data through a single access point. GFEBS consists of six major business process areas bringing various benefits to the Army: funds management; property, plant, and equipment (PP&E); spending chain; reimbursables; cost management; and financials.

4. The creation of content that would benefit O&M reporting:

BIM design content:

- Site map for GIS;
- Site survey for GIS;
- 35% design;
- 65% design;
- Final design;
- Funding and contracting documents and correspondence;
- Specifications.

BIM construction:

- Modifications;
- As-built;
- Equipment as-installed;
- Equipment test data.

BIM operations and maintenance:

- As-built site map and facility;
- Emergency systems;
- Equipment list;
- Equipment warranty data;
- Spaces;
- Utility models;
- Building systems;
- LEED documentation;
- Floor plans.

2.4 Challenge

The objective for this research was to generate an equipment list with the complimentary attributes for operations to review and approve or reject. Using that list, designers, engineers, and contractors must track and record the specified information through the design and construction phases. If documented and updated correctly, the data at handover will match the list developed by operations.

During the site assessment, DPW generated a list of equipment to track. Attributes such as serial number and manufacturer were discussed. After comparing the list formulated at Fort Meade with the GFEBS fields, ERDC developed a list to be tracked for the rest of the project.

Table 3. Generated equipment list using DPW and GFEBS requirements.

Equipment to be Tracked	Attributes of Each Item
Air conditioners Air handler units Fire alarm systems Fuel storage tanks and associated release detection systems Backflow prevention assemblies Boilers and burners Chillers Air compressors Emergency generators Emergency lighting inverters Exhaust, supply and return fans (belt-driven) Smoke detector Kitchen equipment (refrigerators, freezers, ice machines, etc.) Furnaces Water heaters (power burners) Infrared radiant heaters HVAC controllers Security devices/controls (camera, control center) Plumbing system (type) Door (single, double, fire-rated, security lock) Window type and cover Ceiling type (tile, etc.) Wall covering type (paint, vinyl) Flooring (carpet, tile, etc.)	Equipment number Description **Manufacturer data** Manufacturer Manufacturer country Model number Manufacturer part number Manufacturer serial number **Location** Name Location Room **Classification** Class Object type Room Weight Size/dimension Start-up date **Warranty** Warranty start Warranty end Master warranty Vendor Customer postal code End customer postal code Operate postal code Delivery date

With the development of a populated equipment list comes the question of the best technology and format to insert and track data. ERDC proposes that the information be divided between the BIM model and a database. Designers enter initial building data using BIM and corresponding analyzing models. That data then is exported into a database. As data such as serial numbers develop during construction, contractors can interact with the database through a Web interface. At the end of construction, information is collected and stored on the database and turned over to the user.

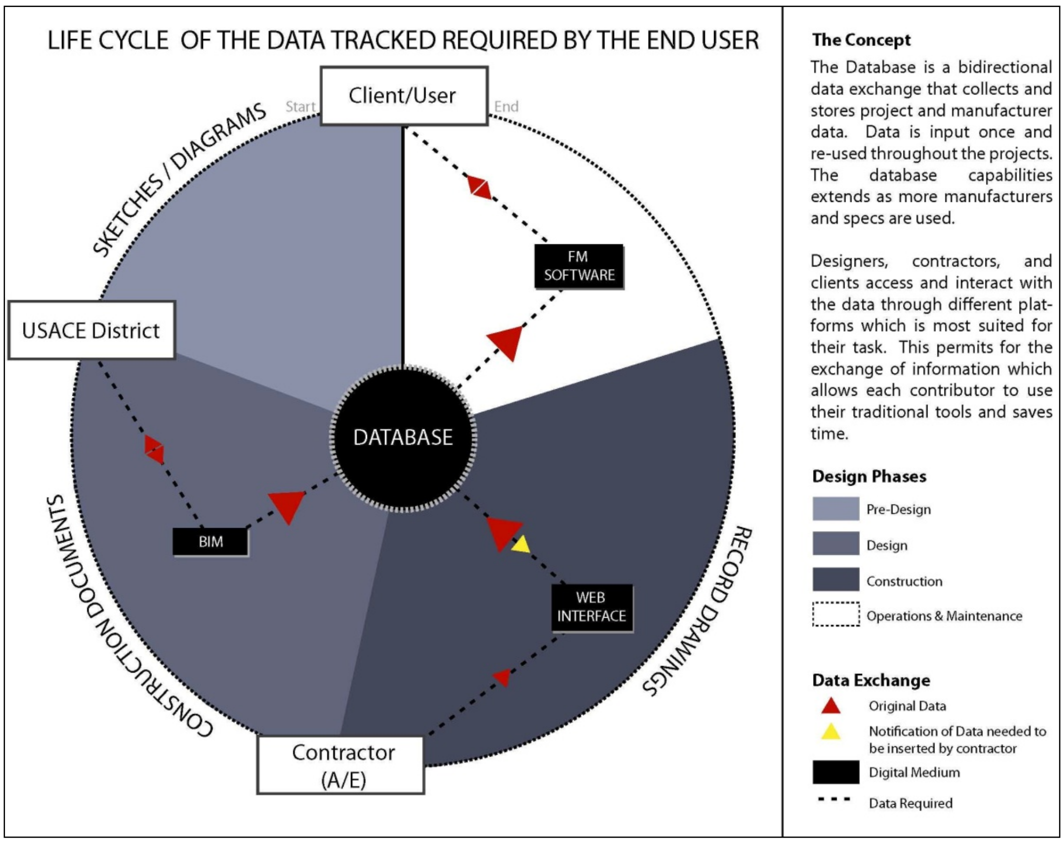

Figure 4. Flow of information during the building life cycle.

3 Design

3.1 CENAN process and technological disadvantages and advantages of designing in multiple BIM software

CENAN designers used a combination of BIM software, such as Bentley Architecture, Revit MEP, and Revit Structures, to model of the AWG Complex. Most of the designers involved in the project were first-time BIM software users. The consensus was that it was very beneficial, but there were some obstacles while designing.

Architect Luis Rosario-Lluveras used Bentley Architecture for drafting the architecture portion of the AWG Complex. In using the software, he found many technical issues. When reported to Bentley, technical support staff were not responsive at first; later, they were able to resolve some of Rosario-Lluveras's issues. Due to the schedule of the project, there had been no time for software training.

Mechanical engineer Jennifer Melendez used Revit MEP to design the mechanical model. She reported that Revit was user friendly, noting it was her first time using it. "Designers see the real effects of drawing," Melendez said. The Revit software, she found, captured mistakes early in design. Negatives of the software, Melendez said, was that it was too time consuming and demanding at the initial design phase. Also, her learning curve caused some setbacks.

Electrical engineer Andrew Chan also used Revit MEP to design the electrical model. He is a beginner at using BIM software. Chan has used Bentley and found that Revit was much easier. He liked that the 3-D presentation was better in Revit. Chan suggested a cheat sheet for keystrokes and software functions. An issue he came across was that the Revit files were too large and would crash the outside system periodically. He suggested the hardware be updated and that separate BIM files in different components be coordinated.

Structural engineer Ali Palen used Revit structures for the structural model. She liked the coordination of Revit, the user friendliness, and how fast it detected issues. Palen recommended that a civil works section be added to BIM.

3.2 Contractual language

The goal of properly capturing and tracking data throughout the building life cycle affects every contractual document in the process. Owners and designers must collaborate in the early stages to outline the intentions and final expectations. Those goals are transmitted to the contractor as proclamation of his or her responsibilities in obtaining the quality and usability of the final deliverables.

In preliminary design, the owner and designer should agree in pre-work documents upon the role that BIM will serve throughout the project, such as scope of work. Using the knowledge and experience from shadowing the AWG, the following contractual language could be used in a proposal to future clients. Sample contract language could be presented as:

SCOPE OF WORK

<u>Presentation and meetings</u>

The DESIGNER shall attend one required meeting to be conducted in LOCATION, a pre-work conference/SDD charrette with OWNER. The DESIGNER shall come to OWNER LOCATION for the conference prior to initiating work. The pre-work conference will include a visit to the project site and to existing facilities at/around the site. OWNER representatives will provide the programming/building requirements at this time.

With the OWNER representatives shall be a Facility Management (FM) representative. The representative shall give an overview of the workflow procedures and the technology currently used in the FM office. The DESIGNER will request information about the capabilities of the FM office's usage of BIM in operations and maintenance in order to structure the time line and technological requirements appropriately.

For this meeting, the DESIGNER shall prepare meeting minutes that shall be the record of discussions at the conference. The DESIGNER shall complete the minutes within three working days of the conference and submit the minutes electronically to all attendees for review and concurrence or comment.

The DESIGNER will set the agenda and perform the charrette. At the planning charrette, the DESIGNER may use LEED to establish a strategy for meeting the sustainability goals for the project, identify all individual credits feasible to reach the goal, and ensure first costs associated with this strategy are captured. This strategy shall be captured on the Project Checklist.

[Note: OWNER is a placeholder for client/owner for whom the work is performed, and DESIGNER represents the district of A/E performing the work.]

The contract between the designer and the client also must contain language that states the roles and responsibilities during design. In the design award contract, sample language could include:

> DESIGNER must supply the FM representative with a template list of equipment and attributes typically used in operations and maintenance. The FM representative will perform a review in order to approve the list to be officially inserted into the contract.
>
> DESIGNER shall enter known information about the equipment using BIM developed by ERDC during the design phase.
>
> The approved list must be included in the contract between the contractor and owner using the 01 33 00 submittal procedures. Blank fields for information to be uploaded during construction shall be specifically noted by the DESIGNER.

The provisions for BIM projects are in the construction contract, in Section 00 73 05, Supplementary Requirements, Attachment A; and in Section 01 33 16, Attachment F.

> Contractor must verify with owner that BIM received is compatible with the facility management software.
>
> Contractor is required to digitally record data using by uploading to the Web interface developed by ERDC.
>
> DESIGNER shall provide the contractor with an equipment schedule approved by the user that specifically lists the information that is required by the owner for facility management.
>
> The contractor shall capture and upload this information to the digital database (hosted by ERDC) as soon as the information is known.

4 Conclusion

The Fort Meade DPW Contractor Building remains in the design phase. The immediate actions are to finalize the software plans for space planning to be used to manage the building, develop the Web interface for contractors, and research the file format that communicates with GFEBS.

DPW has expressed interest in training in BIM and FM software. ERDC has proposed the use of a basic FM software that handles only space organization, since GFEBS is for equipment tracking. Therefore, ERDC will contact the GFEBS system designer to see if any coordination between BIM and GFEBS can take place.

The BIM Primer is a long-term project. ERDC will follow the AWG project through commissioning and handover. The final volume of the BIM Primer will have the results from all three stages: design, construction, and operations and maintenance.

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Appendix A: BIM Utilization Benefits

ecoBI Savings of BIM utilisation – Benefits Chart

(courtesy of Paul King, Bentley Systems, Inc.)

Key
■ Principal beneficiary
□ Secondary beneficiary

Project stage	Benefit area	Design team	Main contractor	Sub contractor	Operator	Description	Benefits	Cost benefit
Preliminary, concept and detail design	Visualisations, animations, and virtual reality	■	■	□	□	Animations, visualisations and virtual reality materials are produced as a by-product of the model. Simulations can help to improve health safety by considering aspects such as working at height - for construction and subsequent facilities management.	- More effective promotion of a scheme and stakeholder awareness - A more effective and transparent design process - Improved health and safety management	
	Coordination and clashing	■	■	□		The virtual model provides an effective and efficient means of coordinating the design elements on a scheme. Although design teams claim to perform coordination and clash detection it is often left to second- and third-tier supply chain partners.	- Clash free, fully coordinated design model - Lower design cost (design is done once only, and done right) - Less burden on the design team during construction	5% saving in design cost
	Design analysis	■				Data from the 3D model can be exported quickly and easily to design analysis packages and the resultant design data can then be imported seamlessly back into the model.	- Faster design analysis - Error-free transfer of data between analysis and modelling packages - Lower design cost and the ability to consider more design options	
	Material schedules	■	■	□		Component and material schedules are generated automatically and accurately from the 3D model, and can be transferred easily to and from proprietary databases or spreadsheets to help estimators, purchasers and designers.	- Quick production of error-free schedules - Smaller estimating teams - Better awareness of costs as the design develops	1% saving in design cost
	Bills of quantities	■	□			Bills can be produced to any standard and format by exporting appropriate data from the model.	- Quick production of correctly formatted bills with fewer errors - Lower cost of production	
	2D drawings	■	□	□		2D drawings are extracted quickly, easily and efficiently from the model. As supply chains adopt a model centric approach, the need for drawings will diminish.	- More cost effective drawing production, with fewer errors - Fully coordinated design deliverables - Accurate and consistent plans, sections and elevation	
	Links to project documents	■	□	□	□	The virtual model can be linked to project documents (such as specifications, risk assessments, etc) and to suppliers' product information, either on or off the Web.	- Easier access to project information for all stakeholders - Better management of component data - More efficient design process	
	Stakeholder awareness	■	■	□	□	The virtual model is a powerful tool that helps to convey complicated design aspects to stakeholders, and information can be tailored easily to suit the audience.	- Improved stakeholder awareness - Easier to secure buy-in earlier in a project - More likely to encourage a good response from potential tenderers	1% saving in design cost
	Design efficiency	■	□	□	□	A model centric approach makes it more realistic for designers to 'do it right first time', and to consider more design options. It also enables more effective and better integrated decision making.	- Greater design efficiency - Better value for the client - More profit for the designers and no erosion of margin in construction	3% saving in design cost

Figure A1. Savings of BIM utilization: preliminary, concept, and detail design (King 2008).

Procurement, construction & commissioning	Trade packages		■	■		Using the virtual model, site teams can produce trade package information easily and accurately for tendering and managing subcontractors. Armed with a better understanding of the project, trade contractors are more likely to 'get it right first time'.	- Easier compilation of tender information - Tenderers receive information that is correct, complete and consistent - Lower tender risk contingencies	1% reduction in build cost
	Construction planning		■	□		Virtual models can be linked to master and sub-project programmes using proprietary software tools, enabling the works (and changes) to be conveyed graphically via the model.	- Improved project programming and better understanding of activities - Better informed stakeholders - Improved health and safety training of site teams	0.25% reduction in build cost
	Buildability & logistics	□	■	■		Buildability and construction logistics checks are performed in the virtual world during the design phase to prevent problems from ever reaching site.	- More efficient site activities leading to lower construction costs - Greater programme certainty - Improved planning of site laydown areas and materials logistics	
	Clash management	■	■	■	□	Design coordination helps to prevent clashes reaching site, thereby eliminating both construction waste and the associated disruption. Fewer queries have to be referred back to the design team because there are fewer errors in the design and the construction team can interrogate the model to resolve queries.	- Clash free, fully coordinated design and construction - Lower construction cost because of less waste and less disruption - Less burden on the design team during construction - Better certainty of project programme	5% reduction in build cost
	Stage payment		■	□		By monitoring planned and actual progress with a virtual model, payment mechanisms can be more accurate and more efficient.	- Better payment mechanisms - Fewer contractual disputes - Improved transparency of processes	
	2D drawings	■	■	■		Site teams can produce drawings quickly and easily from the model if required, but the need to generate drawings on site is reduced.	- Less burden on the design team during construction - Quicker access to better design information by site teams - More effective interaction with specialist suppliers and subcontractors	
	Awareness of works		■	■	□	The virtual model can be used to convey elements of the project to stakeholders, and to simulate the impact of, for example, incidents that cause congestion on site. It can also help to clarify key interfaces between FM management and games operations.	- Improved understanding of matters affecting health and safety on site - Greater transparency of site activities - Less disruption to programme	0.25% reduction in build costs
	As built information		■	□	■	As-built information can be produced easily and more accurately because the model is kept current through the construction period, ensuring that the facilities manager will receive high quality data.	- Easier to produce high quality as built data for handover - Lower cost of producing as built information	0.05% reduction in build costs

Figure A1 (continued).

Operations, FM & legacy	Population of FM database		□		■	The virtual model can be used to automatically populate a facilities management asset database at the end of construction, generating a large saving in staff resources and cost.	- Swift, accurate population of the FM database with good quality data - Lower cost of establishing the FM system	£k one-off saving
	Managing operations				■	The model can be linked to an FM system to help manage space, assets, building maintenance, property and lease details, cable infrastructure and telecommunications. Model data can be loaded onto handheld devices for mobile audits and maintenance work.	- More efficient facilities management - Staff have easy access to high quality record information - Lower cost of operations (including auditing, benchmarking, etc)	
	Managing new works and change	□	□		■	Provision for maintenance can be built into the design more easily, building systems can be viewed using the model, and access by maintenance workers can be simulated.	- More efficient design and implementation of new works - Improved health and safety - Lower cost of managing the facility as it evolves over time	Annual saving
	Links to product information				■	The virtual building can be linked to project documents and to suppliers' product information, either on or off the Web.	- Easier and quicker access to product information - Lower cost of sourcing data	
	Links to BMS systems				■	Environmental controls, sprinkler systems, lifts etc. can be link to the model so that these can be managed graphically	- More effective facilities management	
	Links to security systems				■	The model can be linked to security systems to assist with access control, closed circuit TV and fire detection.	- More effective facilities management	
	Links to stock control system				■	Stock control items, such as office partitions and furniture, can be managed by linking them to the model.	- More effective facilities management	
	Hazardous material location	□	□	□	■	The construction industry does not use hazardous materials but if future legislation were to require, say, all glass fibre insulation to be located in a building, then the model could be interrogated to show its position.	- Lower cost of complying with legislation	
	Building cloning	■			□	The model contains all of the information needed to build and manage a facility, and it could be used to easily duplicate that facility (or parts of it) elsewhere.	- Much reduced cost or providing similar facilities in future	
	Knowledge management	□			■	The model is a valuable repository of project knowledge, comprising data on design, construction and operation. Such data could be shared with potential purchasers of a facility, or used to assist with due diligence processes when it changes ownership.	- Easy referencing of project knowledge - Lower cost of due diligence activities	
	Sustainability	□			■	The model contains data relating to sustainability, such as the location, quantity and quality of reusable materials.	- Quick access to high quality sustainability data - Efficient sustainability reporting, auditing and management	
	Decommissioning	□	□	□	■	The virtual model contains important data about items such as structural walls that decommissioning contractors can use to minimise the risk of, for example, uncontrolled collapse.	- Safe decommissioning - Lower risk contingencies in decommissioning tenderers' quotations.	

Figure A1 (concluded).

Appendix B: Fort Meade Site Assessment

ERDC, along with Bentley Systems, conducted a site assessment at Fort George G. Meade. In this appendix are the agenda, goals and objectives, and interviews.

Agenda

Asymmetric Warfare Group Complex Site Assessment
August 16-18, 2011
Fort George Meade, MD
Attendees: ERDC, Bentley Systems, Fort Meade DPW

Objective:

The purpose of the Fort Meade, MD site visit was to conduct a series of meetings to get an understanding of the different aspects, opportunities, and requirements of building information modeling (BIM) to better assist the operations and maintenance of the Asymmetric Warfare Group Complex project.

Tuesday, August 16, 2011

1. Site assessment kickoff (Review goals and objectives)
    a. ERDC
    b. Bentley Systems
    c. Andy Bagnall
2. Fort Meade campus tour
3. Fort Meade Interviews (see interviews)
    a. Sal LiCausi (GIS)
    b. Paul Sylvester (DPW Engineering)
    c. Tim McPherson (DPW Engineering)
    d. Tony Karwoski (Energy Engineering)
    e. Carole Cramer-Prait (DPW Engineering)
    f. Cliff Chatman (Contractor for GFEBS)
    g. Cathleen Dodson

Wednesday, August 17, 2011

1. Introduced the IDEF Modeling Approach

   a. Attendees

      - ERDC
      - Bentley Systems
      - Tim Mc Pherson
      - Tony Karwoski
      - Andy Bagnall

2. Interview with Joyce Patenade (Real Property)
3. Overview of expectations and goals of BIM Primer

   a. Attendees

      - ERDC
      - Bentley Systems
      - Andre Johnson
      - Bill Snyder
      - Alice Lomax

Thursday, August 18, 2011

1. Wrap-up meeting

   a. Attendees

      - ERDC
      - Bentley Systems
      - Alice Lomax
      - Joyce Patenade
      - Bill Synder

Goals and objectives

1. Understand the different aspects of Building Information Models

   a. Design Model
   b. Construction Model
   c. O&M Model

2. Usage of BIM (opportunities for use of BIM)

   a. BOID (Business Operations and Integration Division)

      i. Chief Andre Johnson

    b. AWG (Asymmetric Warfare Group)
        i. New York and Baltimore District USACE
        ii. Facility Manager Art Bailey
    c. TBD (3d City, Campus Model)
3. Requirements of BIM
    a. The Model composition (what is necessary to maintain the integrity of the model)
    b. Software
    c. Training
    d. Processes and workflows to take advantage of BIM
        i. What needs to be modified to use BIM in the Process
        ii. For example a work order to modify a space is different if the building has a BIM vs a 2d CAD floorplan.
4. Where will BIM first come into the Installation
    a. Are there buildings being Designed and Constructed using BIM
        i. DISA Defense Information Systems Agency
        ii. DMA Defense Media Activity
    b. Are there plans to maintain the delivered BIM
    c. What format are the BIM in (Revit, AutoCAD, Bentley)
    d. What standards are in place for BIM deliverables in the contract language
5. Automated process for loading GFEBS from BIM
    a. 1354 automation
6. <u>Challenges:</u>
    a. BIM for O&M is not usable due to errors
    b. Advanced HVAC Systems cannot be managed (Skill sets missing)
    c. Site information not in format used by in-house GIS (.shp)
    d. BIM not used in generating work orders (Skill sets and tools missing)
    e. Very long delay in getting BIM from Corps District
    f. No incremental BIM deliverable (everything in one package)
    g. BIM needs to provide data for O&M corporate systems (GFEBS and others)
    h. Establish and validate that standards are in place and used for delivery of data (cross walk between BIM, GFEBS, GIS and other

corporate systems) (Recognize that individual Installation may have different systems)

i. LEED compliance begins at Design, renewable technologies and other Federal compliance

7. Questions: (1 and 2 for information)

   a. Can we still do 2d CAD after we receive a BIM for a specific building?

      i. Yes, but the BIM quickly gets out of date, but it can be updated by converting each WO into the model (ORNL).

         - Took delivery of BIM continued 2d CAD and then updated and now manage the building using BIM as part of the WO process.

      ii. Today it is preferred that installations prepare for delivery of BIM and have inplace training staff that can maintain the BIM once it is delivered.

   b. Does there need to be inplace a Directive stating BIM Compliance

      i. It is best to have a date after which any BIM deliverable is going to be maintained using the BIM tools.

Interviews

August 16, 2011
Attendees: ERDC, Bentley, and Andy Bagnall (DPW)

Department: GIS
Representative: Sal LiCausi
Comments:

The level of the quality of the as-builts make the files difficult to be used. (layers, broken segments, wrong formats)

The as-built drawings are delivered to the installation too late. Installation is omitted from the project throughout a design and construction phase. Often as-builts arrive 2 years after a project is done. Recommend being copied on interim submittals.

No known document that outlines the standard procedure between the districts and the installations on who has which responsibility

Deliverables aren't clearly defined in the initial contracts (by the district).

CAD/BIM Center doesn’t enforce the standards for every district to comply. Not all districts operate the same.

Department: Real Property
Representative: Joyce Patenade

Appointment: Wednesday at 2:00 pm

Department: DPW Engineering
Representatives: Paul Sylvester & Tim McPherson
Comments:

Design projects use the minimum requirements for systems, and it creates problems such as mold. Most failures are by the HVAC system, very few structural failures. (talk to Carole)

Systems used: Sharepoint and IFS (the current software), but switching over to GFEBS (General Funds Enterprise Business System - government system)

Department: Energy Engineering
Representatives: Tony Karwoski
Comments:

Buildings are commissioned improperly

What’s the impact of value engineering on BIM buildings?

Turnover is currently during handover; should be during as soon as equipment is installed.

Information is documented, BUT the information documented even states the commissioning was wrong, but signed off anyway.

Energy bills are massive due to overcooling and systems not working properly.

40% - 50% energy can be saved if systems were commissioned properly.

Federal facilities must meed the energy mandates; however the district doesn’t deliver the documents of equipment to the installation used until after it’s installed and commissioned (in as-builts)

Building management uses systems that small off-name brands that some go out of business and are no longer supported.

Disastrous process to recall installers to fix the equipment.

Department: DPW Engineering
Representative: Carole Cramer-Pait (ME)
Uses Microsoft office

Uses square footage from real property a lot

Databases are a good idea, but they aren't up-to-date.

Real problem, DPW doesn't contract out the issues to those who have the necessary skills to fix the problem.

Gaps in information with the history or projects.

Department: Contractor for GFEBS
Representative: Cliff Chatman
Comments:

Assisting with the transfer from IFS to GFEBS

Not just a financial system

Will send us a spreadsheet.

Department: Service Desk
Representative: Kevin
Comments:

Written up in GFEBS

Sent to contracting (currently uses Maximo, will switch to GFEBS)

Fort Meade Notes – Day 2
Group meeting at Recycling Center

August 17, 2011

Staffing

One concern is the manpower to properly oversee the site facilities, and to fix problems. In comparison to NSA staff (located on the installation), they are adequately staffed to handle all tasks of everyday maintenance, along with inventory, space planning, repairs, and emergencies.

Quality of the Delivered Documents

Standards again need to be enforced and properly stated throughout DPW to expect the same product each project.

Questions:

Is there a way for BIM to validate standards are in place in the BIM?

Is it possible for the Corps to have contractors sign off that the deliverables meet the outlined standards and are responsible if they don't? Contract language?

Energy & Commissioning

Commissioning needs to be properly documented, and retainer should NOT be released until the system is working as designed. However, the design should be verified and RE-verified that the calculations are correct for the building and meet federal mandates.

Federally required:

- LEED Silver
- ASHRAS 1891
- EISA 2007
- EPACT 2005

A buildings energy system is 99% the problem on the new construction.

Warranty expires before building is fully occupied. A longer warranty is needed on these new and complex systems. Also the policy to recall an installer needs to have stronger language in the contract and enforced by the project manager. Unknown, small businesses should be avoided if possible. The systems have been too complex and too customized for anyone else to work on them, but the installer. It's hard to contact the installer, that's if they haven't gone out of business.

The commissioning agent should be a THIRD PARTY. The contractor should NOT be allowed to check his own work.

"We need to start thinking about SCADA now. Eventually, we need to be concerned with how we all tie into the grid."

Testing

Testing should be done during construction, and should be properly documented. Also either a USACE design team member or an installation representative should be on site during testing.

It has happened in the past where there is no building code official, and contractors aren't compliant with the code.

Value engineering has also impacted the quality of building materials. We have many problems with the final product deficiencies, but we can't do anything because they meet the minimum standard.

Appendix C: CMMS Software

General Fund Enterprise Business System (GFEBS)

GFEBS is the Army's new Web-enabled financial, asset, and accounting management system that standardizes, streamlines, and shares critical data across the Army, Army National Guard, and Army Reserve. The goal of GFEBS is to capture transactions and provide reliable data to help Army leadership make decisions. Leaders can retrieve data through a single access point.

GFEBS provides significant benefits to the Army's financial management portfolio. At the operational level, it improves decision-making ability because of accurate and real-time cost data. GFEBS consists of six major business process areas that bring various benefits to the Army: funds management; property, plant, and equipment (PP&E); spending chain; reimbursables; cost management; and financials.

GFEBS was developed and is managed by a private company, Eagle Management Systems, LLC. EMS specializes in business counsel, enterprise architecture, enterprise resource planning (ERP) implementation support, construction management, and strategic outsourcing services. Two EMS employees are at Fort Meade, assisting DPW with its switch from IFS, its former maintenance management software, to GFEBS.

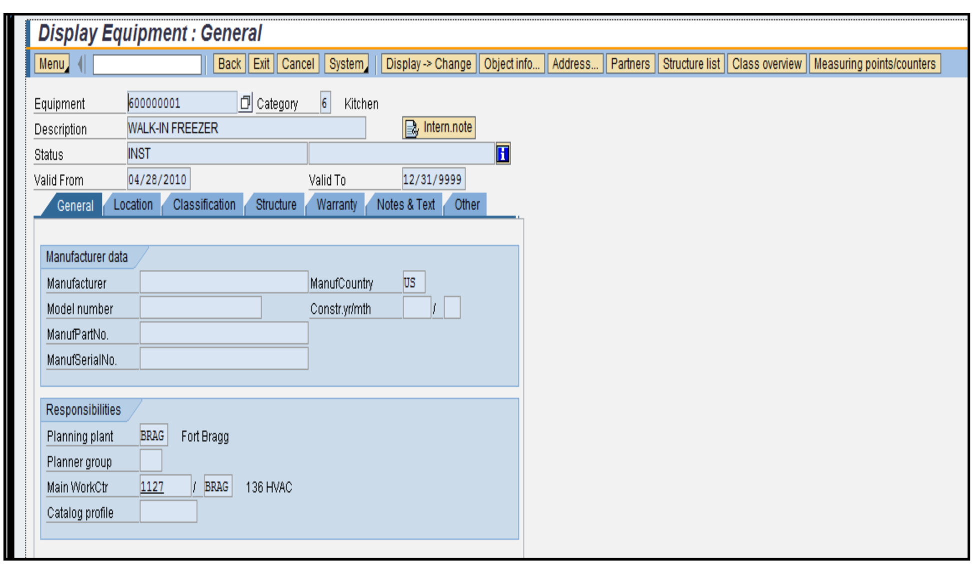


Figure C1. General information tab on the GFEBS interface (EMS 2011).

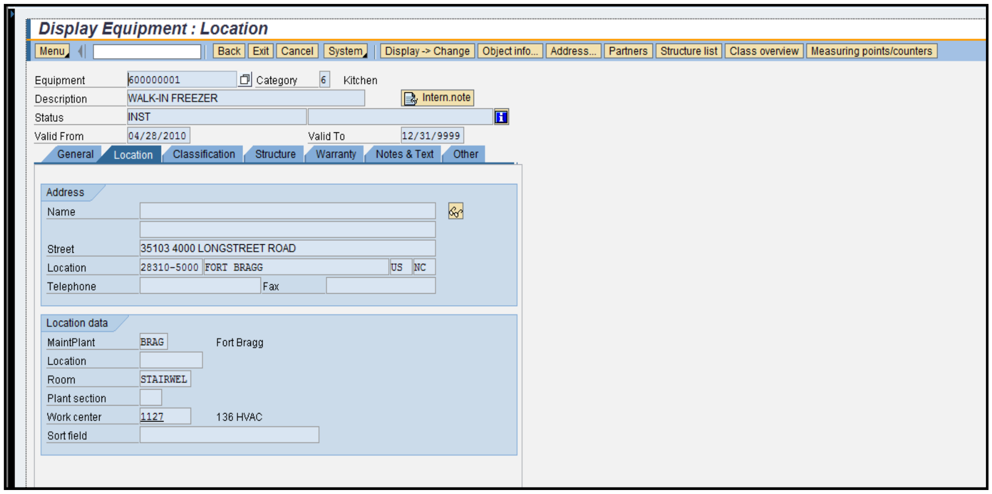


Figure C2. Location information tab on the GFEBS interface (EMS 2011).

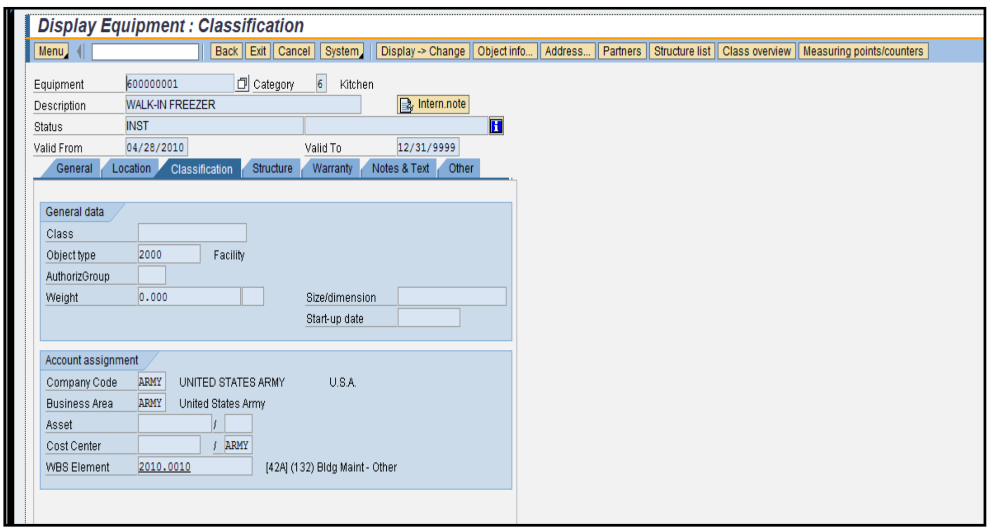


Figure C3. Classification information tab on the GFEBS interface (EMS 2011).

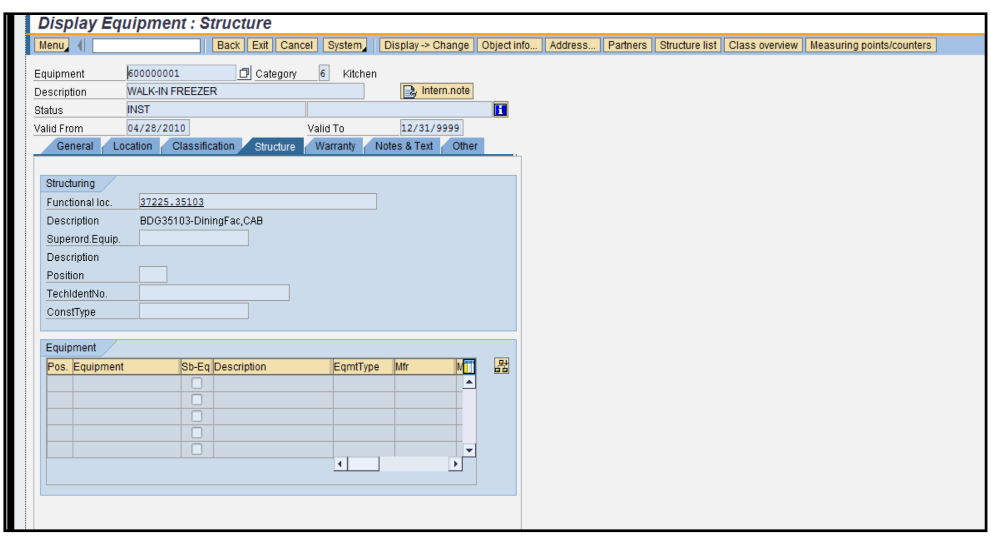


Figure C4. Structure information tab on the GFEBS interface (EMS 2011).

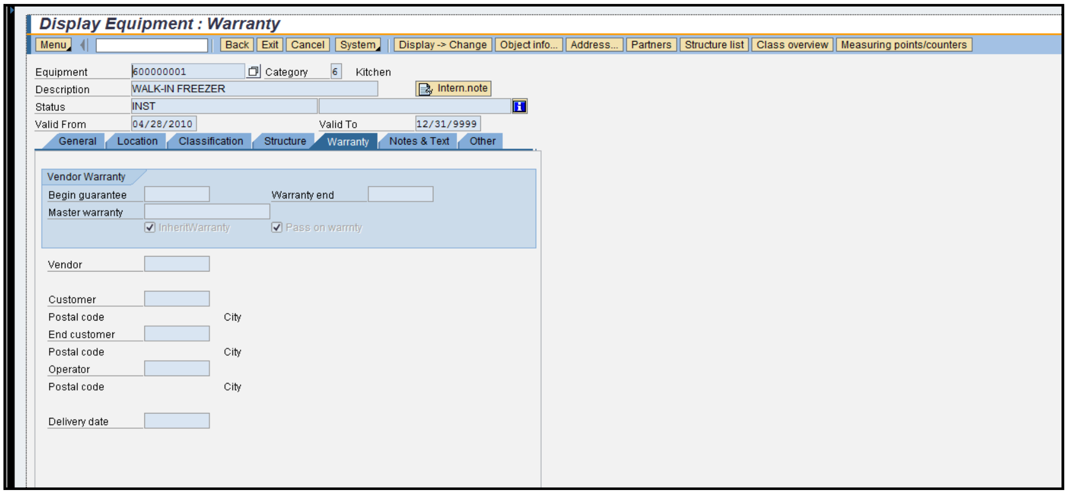


Figure C5. Warranty tab on the GFEBS interface (EMS 2011).

Evolve FM

Evolve FM is a facilities management software that is affordable and easy to use. Facility information can be accessed safely through an organization's intranet, corporate network, or the Internet. Access may be granted to everyone or limited to certain users. In Evolve FM, space and assets can be easily organized based on allocation, space type, occupancy, etc. The information needed can be obtained by using the search engine. Evolve FM allows the user to take advantage of BIM data by giving the necessary tools to extract and manage information such as exterior property level, equipment, data jacks, etc.

Evolve FM Plan Room is a repository that houses the electronic documents of a facility. It provides one safe location for as-builts. The modules of Evolve FM software are:

- Space Management;
- Asset Management ;
- Move Management w/Move Scenario;
- Maintenance Management;
- Plan Room;
- Grant Management;
- Lease Management;
- Project Checklist;
- Dashboards.

Figure C6. The Evolve FM Plan Room (CAFM 2011).

Table C1. Features and capabilities of Evolve FM.

Evolve FM Features			
Database	Interface	Drawing	Scalable Implementation Options
- SQL database - Open API - Google Maps integration - Data import and export - Functional level and group security - "Outside-the-Building" capability - FICM space classification - Document inventory	- Microsoft Outlook - Adobe Flash Player - Collapsible ribbons - Explorer-type menu tree - Collapsible panes, large viewing area	- Label zoom control - Full layer control - Proportional hatching - Dynamic, interactive plan views - Drag and drop - Graphical reporting and printing	- Stand-alone network - Web-based, concurrent licensing

Bentley Facilities

Bentley Facilities offers fast and easy access of space and asset information through 2-D and 3-D models, labels, or facility maps.

Bentley Facilities V8i combines MicroStation V8i and Projectwise V8i to create a collection of plans, documents, and database information. The software allows the user to capture and organize new and existing information in the document- and asset-management database. Bentley Facilities includes ProjectWise Integration Server, ProjectWise Clients, Bentley Enterprise Facility Management (EFM) Baseline, Bentley Facilities Space Planner, and Bentley Facilities Web Reports.

Bentley EFM Baseline offers the ability to make better decisions in facilities and asset management. Users can achieve structural improvements in productivity and efficiency, and can obtain a complete overview of activities and costs within the facility. Communication will be effective between departments. Bentley EFM Baseline will help maintain satisfaction through closer contact with clients. Users will be able to manage the workplace to control and apply legislation and safety issues. The software also will give space-planning insight by optimizing space utilization and occupancy.

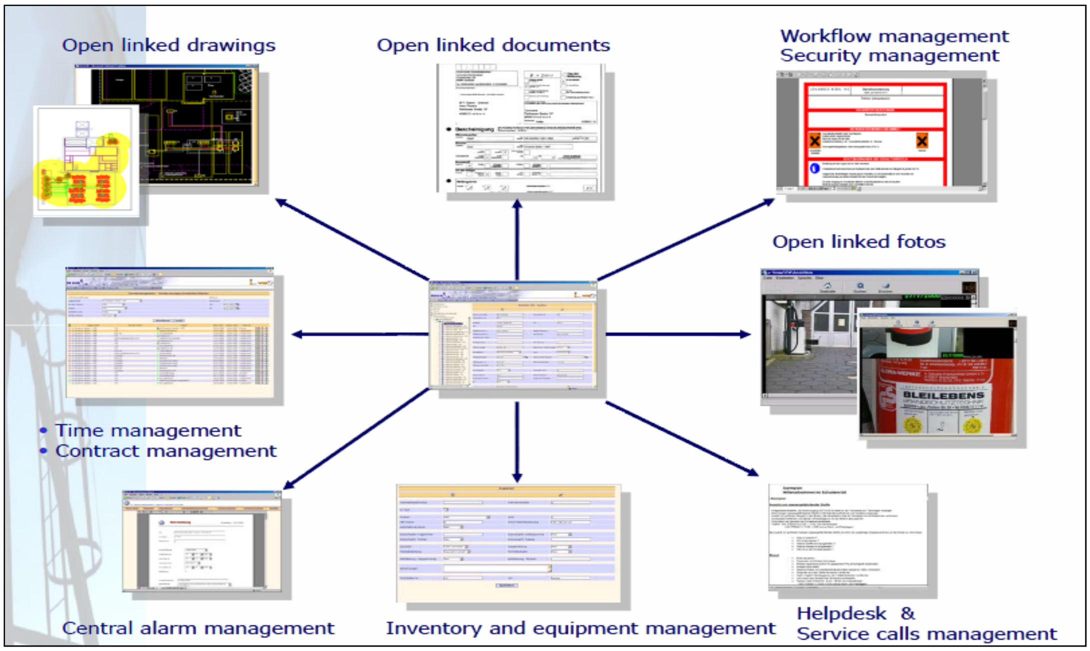


Figure C7. Bentley EFM baseline functionality (Bentley Systems).

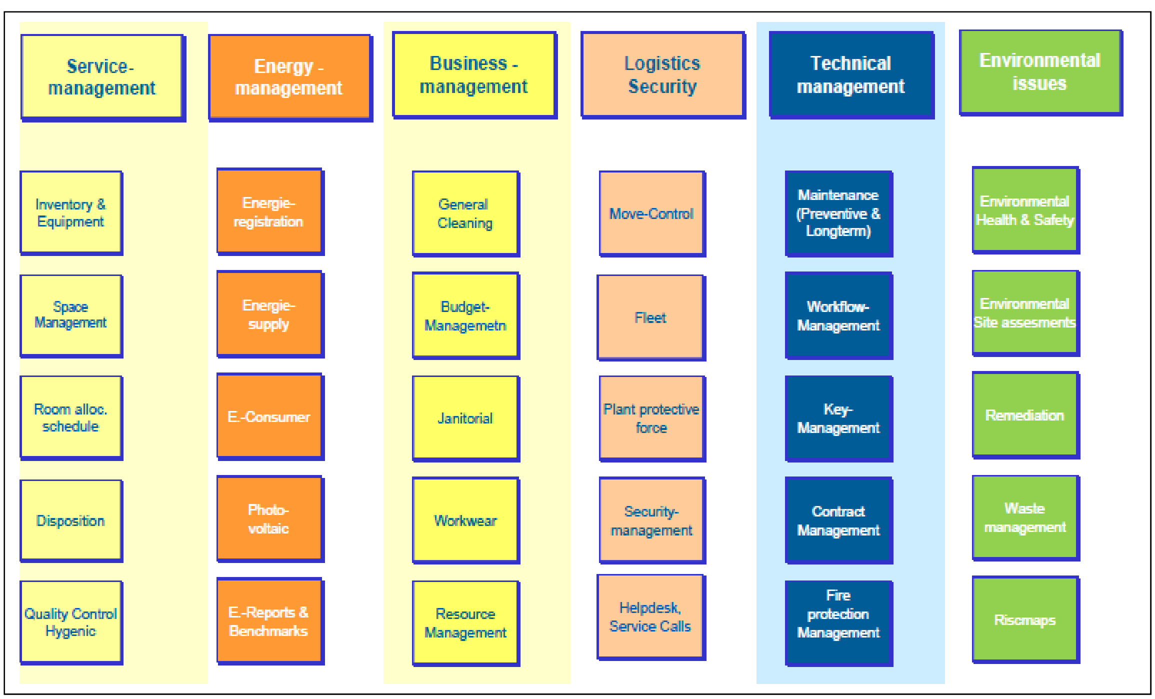


Figure C8. Bentley EFM modules (Bentley Systems).

Bentley Facilities Space Planner reconnects the workflows of the owner and subcontractor. The owner can export floor plans and ProjectWise database information to the subcontractor through the program's Briefcase. The subcontractor then edits the data. The owner receives the modifications from the subcontractor and puts it back into the ProjectWise database.

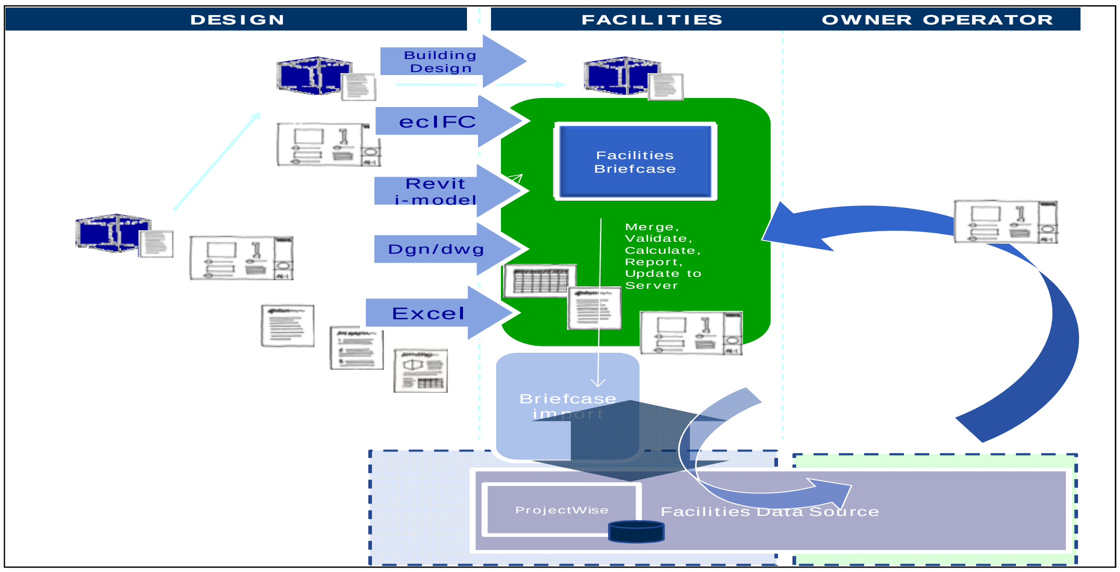


Figure C9. Bentley Facilities Space Planner functionality (Bentley Systems).

Bentley Facilities Web Reports allows facility managers to create and run reports of Bentley Facilities data, as well as external data. Users can access dashboards and predefined reports, charts, and drill-down reports. They also can schedule reports for distribution. Users can use ad-hoc style reporting to get results with simple drag-and-drop operations.

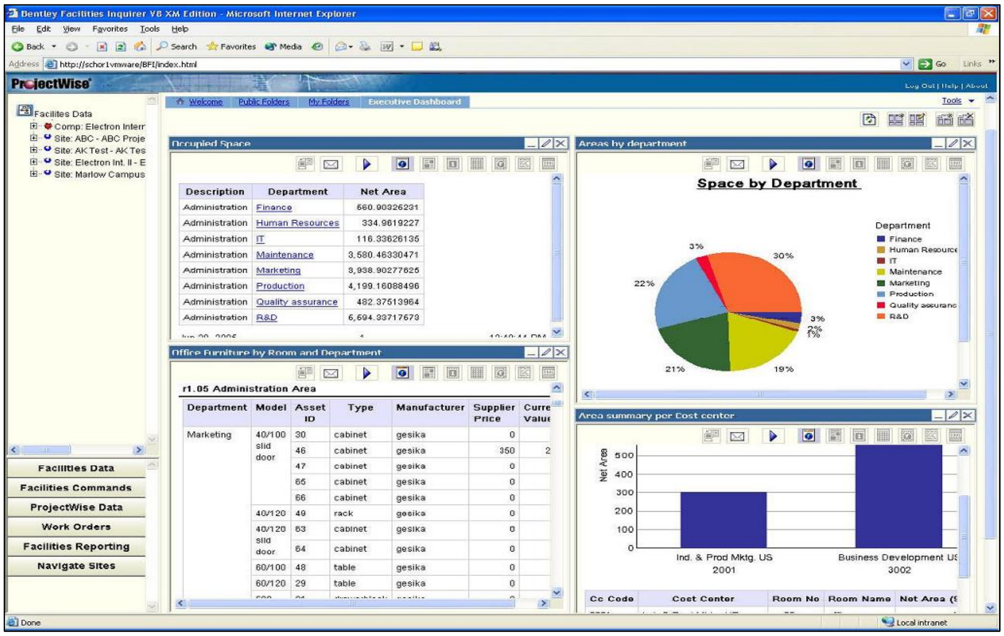


Figure C10. Bentley Facilities Web Reports (Bentley Systems).

Appendix D: BIM + FM Case Studies

FM Systems: National Aquarium, Baltimore, Maryland

Project Summary	The aquarium is divided into three buildings that house exhibits featuring 16,500 animals of 660 species.
Project Team	Cambridge Seven Associates, Whiting-Turner Contracting Co., Barton Malow Company
Software Used	FM Systems, Autodesk DWF
Project Budget	$21.3 million
Data Tracked	Status of the operation and equipment maintenance schedule

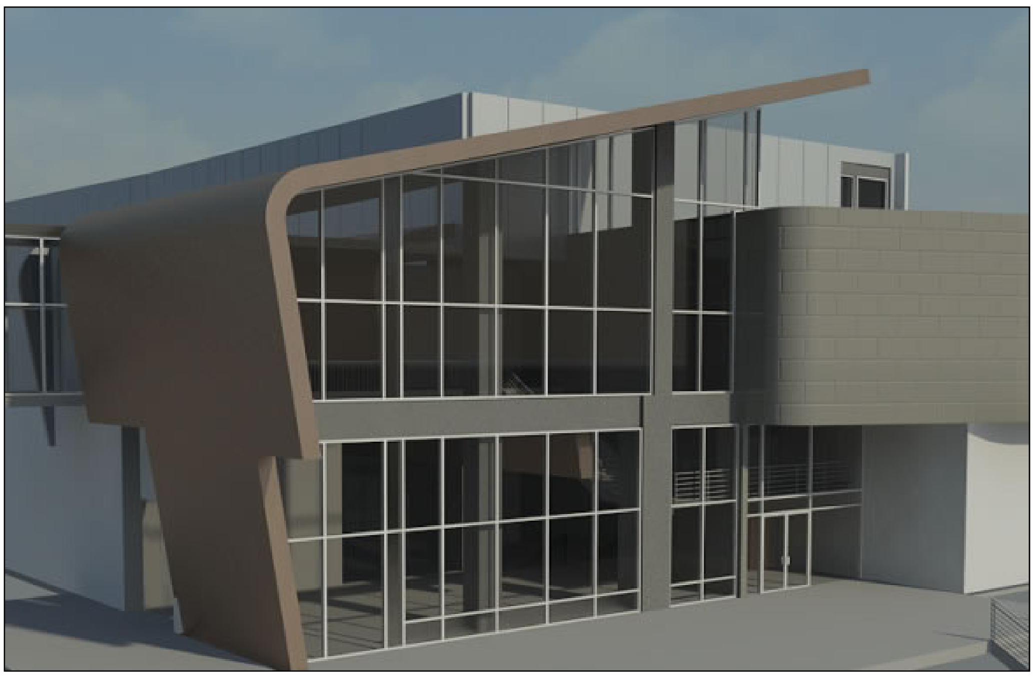
Figure D1. National Aquarium project summary.

A leader in integrated workplace management systems, FM Systems delivers solutions to help manage workplaces more efficiently and effecttively. The solution is to integrate design Web format (DWF) capabilities with AutoCAD software to give customers access to spatial information contained in workplace design files. It also displays workplace data on dynamically generated DWF floor plans.

FM Systems collaborated with Autodesk DWF to drive the crucial visualizetion component of its facilities management solution. FM Systems easily configured the solution to automatically publish DWF files from DWG files. DWF files also are easy for non-CAD users to view and review, can be generated dynamically, and adapt readily to Web-based applications.

The National Aquarium decided to switch its work-order process from paper to an online solution. It implemented FM: Interact, which manages the organization's work orders and all its as-builts in DWF. The maintenance staff can view equipment drawings and schedules online, with no CAD experience required.

Bronco BIM initiate: Western Michigan University, Kalamazoo



Project Summary	In-house research to test the benefits of BIM. In 2010, 80 % of the 8-million-sq-ft campus was digitally modeled using Autodesk Revit Architecture.
Project Team	WMU Civil Engineering Department, WMU Facilities Management, Kal-Blue, Autodesk
Software Used	Autodesk Revit Architecture, Autodesk Revit Structure, Autodesk Revit MEP, Autodesk Navisworks Manage, AutoCAD MEP, Autodesk Civil 3D
Project Budget	Reasonable, able to achieve by using student labor
Project Savings	Effective identification of targets for renovation and retrofitting
Data Tracked	Baseline AIA E202, Level 200
O&M Resource	Laser scans imputed additional information that upgraded models to Level 400 (E202).

Figure D2. Bronco BIM initiative project summary.

In 2008, Western Michigan University introduced BIM and Autodesk Revit to its curriculum. The Department of Civil Engineering partnered with Kal-Blue to launch research that studied BIM throughout a building's life cycle. Kal-Blue was brought in for guidance and training. Its personnel walked WMU through the AIA's E202, a document that helps determine how much detail to show in the models. Kal-Blue also developed the best practices for the design team to follow.

Using student labor, 115 buildings on campus were modeled in Revit. The models then were integrated with energy analysis software to make better decisions about energy consumption. WMU also has been able to use the models to complete renovations in a timely manner.

Maximo integration: NASA Langely Research Center (LaRC), Hampton, Virginia

NASA launched a five-phase facility modernization program to construct six new buildings and renovate two on the campus of Langley Research Center (LaRC) in Hampton, Virginia. Facility managers were using Maximo for work orders and purchases. However, to track equipment, employees manually filled out Form 491. NASA LaRC partnered with GSA and Ecodomus to implement BIM technology, to integrate with Maximo downstream.

The partnership allowed for the BIM and Ecodomus software to transfer the data tracked to an electronic version of Form 491. The model was updated during construction; therefore, the information was accurate throughout that phase. After turnover, the model was linked to Maximo, and at any moment a digital representation of the part or space can be referenced. Ecodomus software also allows users to insert photos.

As a result, NASA LaRC could specifically outline the requirements for data and documentation in future building contracts.

Project Summary	A five-phase operation to construct six new buildings and renovate two buildings during a 15-year facility modernization program
Project Team	NASA, GSA, and Ecodomus
Software Used	Autodesk Revit Architecture, Autodesk Revit MEP, Autodesk Revit Structure, Autodesk Navisworks, CADduct, QuickPen, Ecodomus FM, IBM Maximo
Project Budget	$200 million
Data Tracked	Information needed for Form 491, used by NASA's O&M employees

Figure D3. NASA Langley Research Center project summary.

Ohio State University Medical Center, Columbus

Project Summary	To collect missing building information to manage the hospital more efficiently
Project Team	Ohio State University, Autodesk, Evolve FM
Software Used	Autodesk Revit Architecture, Autodesk FM Desktop, Evolve FM
Project Budget	$200 million
Estimated Cost Savings	$40,000 per year
Data Tracked	Spaces, equipment, administration files

Figure D4. Ohio State University Medical Center project summary

ERDC interviewed Joe Porostosky about the facility management software used at Ohio State University Medical Center. Porostosky is the manager of Facilities Information and Technology Services. The department manages 55 buildings on the campus, tracking room numbers, space IDs, organization codes, etc.

At one point, the department used the facility management system Tririga, which supported all FM functions. The interface was not user friendly, and the software was expensive. The department also used Autodesk FM Desktop, a facility management software that is a space information system. It took three months for the department to implement due to the old interface access.

Facilities Information and Technology Services was the first customer to use Evolve FM. The software has a modern platform, only uses space, and is user friendly and inexpensive.

The department's building models are in AutoCAD, but employees will start using Revit BIM models. The process to capture the necessary information is simple. Changes are made to the existing building's model. Afterward, the changes are exported from AutoCAD to DWF file format. The DWF file is imported to Evolve FM. The facility planners track current and future space use in Evolve FM. Engineers, O&M, and construction managers use the as-builts in Evolve FM Plan Room.

FM process: Sydney Opera House, Australia

The Sydney Opera House (SOH) is a large, complex structure, housing equipment and activities that are equally complex. The building has reached a milestone age in terms of condition and maintenance of key public areas and service systems, function of spaces, and implementation of long-term strategic management. The O&M and large technician and contractor group demand a more integrated system that accommodates the constant changes in the facility.

In 2005 , the Australian Cooperative Research Centre for Construction Innovation embarked on the SOH FM exemplar project to identify FM industry best practices. The SOH developed a BIM to be used for full life-cycle management. The Industry Foundation Class (IFC) data model was an integral part of the SOH model development. IFCs were used to transport the structural design model to the BIM application for further modeling, with further exports to the FM software via IFCs. The integration of FM applications and IFC-compliant BIM is in its infancy. To support the FM process using the IFC model at the SOH, the team developed guidelines and modeling practices and formalized them into specifications.

Project Summary	Multi-venue performing arts center with a modern expressionist design and a series of large, precast concrete shells
Project Team	Civil & Civic Construction Firm, Hornibrook Group Pty Ltd, Jorn Utzon (architect), Ove Arup & Partners (structural engineers)
Software Used	Bentley Structural, ArchiCAD, IFC Viewer
Project Budget	$102 million
Data Tracked	Building maintenance, accounting, building presentation, asset value management

Figure D5. Sydney Opera House project summary.

BIM benefited SOH's facilities management by providing information that is easily shared and reused by the contractors and staff of the organization. BIM also is used in upgrade and refurbishment projects, and can control whole-life costs and environmental data leads for predictable building performance and tighter budget planning.

BIM implementation: University of Southern California (USC) School of Cinematic Arts Complex, Los Angeles

Project Summary	Four-story, 137,000-sq-ft facility that houses classrooms, production labs, administrative offices, a theater, exhibition hall, and cafe
Project Team	Urban Design Group, Hathaway Dinwiddie, TBD Consultants, IBE Consulting Engineers, KPFF Consulting Engineers, View By View, Gregory P. Luth and Associates, Inc.
Software Used	Autodesk Revit Architecture, Autodesk Revit MEP, Autodesk Revit Structure, AutoCAD Civil 3D, Autodesk Navisworks, Autodesk 3ds Max Design, Ecodomus
Project Budget	$165 million
Project Savings	Phase 1: two months ahead of construction schedule and 2% saved; Phase 2: three months ahead of schedule and 10% under budget
Estimated Energy Savings	30% less than required by California's energy code.
Data Tracked	Equipment numbers, electrical capacities, fan speeds
O&M Resource	Hyperlinks to warranties and operations manuals

Figure D6. USC School of Cinematic Arts Complex project summary.

The multi-building complex at the University of Southern California (USC) School of Cinematic Arts was completed in 2010. USC is the first to offer a bachelor of arts degree in film; it is ranked the top film, television, and media school in the country. The project was delivered ahead of schedule and under budget.

The commitment to BIM was driven by the owner, who had saved $10 million on another project using the technology. The commitment was further supported by the project team, which used Navisworks for cross-disciplinary collaboration, coordination, and clash detection. Proving that experience is the greatest teacher, the project team took into account the benefits of using BIM during facilities management.

In Phase 2, USC worked with the project team, installation contractors, and commissioning agent to incorporate an as-built facility date into the Revit models (Autodesk 2010). A user interface linked the Revit models and data to USC's O&M platform, giving it a more accurate and interactive visual capability. Users were able to access data and documents quickly, retrieve live performance information, and view 3-D graphics of system components.

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14. ABSTRACT
The architecture, engineering, and construction industries are pursuing process and technological innovations to save time and money and to enhance the quality of projects through the design, construction, and handover phases. Building Information Modeling (BIM) is a new technology designed to improve this process.

The U.S. Army Engineer Research and Development Center (ERDC) is making an effort to implement BIM. The U.S. Army Corps of Engineers (USACE), New York District (CENAN), requested assistance from the CAD/BIM Technology Center at ERDC's Information Technology Laboratory, Vicksburg, Mississippi, to research the benefits of BIM throughout the life-cycle process with the aim of improving the quality of its services and provide a competitive advantage. The Asymmetric Warfare Group Complex (AWG) at Fort Meade, Maryland, served as the pilot project, depicting the BIM process during the design, construction, and handover phases. ERDC, CENAN designers, Bentley Systems, and the Fort Meade Department of Public Works (DPW) joined together to capture and deliver real-time building information.

This BIM Primer report documents changes in the building process and the supplemental software required to deliver accurate record drawings and data documentation. This report covers the initial parts of the project, including research of BIM products and the design phase of the AWG endeavor. During the early stages, Fort Meade DPW personnel outlined the data required for operations and maintenance, as well as facility management software they are using and would like to use. ERDC believes that including the end user in the design phase will result in the extension of BIM benefits in the latter phases of a building's life cycle.

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